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Capture of plateau runoff by global positioning system–guided seed drill operation

J.D. Williams, D.S. Long, and S.B. Wuest

Abstract: Contour seeding has long been recommended as a means of detaining water on hillslopes, increasing infiltration, and reducing runoff and soil erosion. Highly undulated landscapes with complex slopes, such as those found in the inland Pacific Northwest, have stymied application of this practice. This study investigated the potential usefulness of using digital elevation models (DEMs) and global positioning system–based guidance systems to efficiently and effectively conduct terrain contouring seeding on a small portion of a field to intercept concentrated runoff. The objectives were to (1) assess the potential for contour planting to capture water that collects on plateaus that otherwise would run off and form severe rills and (2) to determine the resolution and accuracy of terrain representation by DEMs for deriving routing information for planting on elevation contours. A preliminary infiltration and runoff study was conducted in a cultivated field, in a Ritzville silt loam (coarse-silty, mixed, superactive, mesic Calcidic Haploxerolls) with 0% to 20% slopes. Planting was performed with a deep-furrow drill, creating furrows 20 cm (7.9 in) deep. Measurements of the amount of precisely contoured area needed to capture water introduced through furrows perpendicular to the contour furrows show this technique has the potential to increase detention storage, infiltration, and consequently, to influence overland flow and erosion processes. A DEM was developed from data representing global positioning system collection at three different implement widths: 3, 6, and 9 m (9.8, 20, and 29.5 ft). Digital elevation data were collected with a real-time kinematic global positioning system and were processed using four software interpolation methods to develop surface models. The ability of each interpolation method to accurately create contour paths for equipment to follow was compared to points established on the ground with a laser-level. Our results demonstrated that a strip of deep-furrow seeding precisely contoured on the upper shoulder slope should provide sufficient detention storage to capture and hold the runoff from a 100 y, 24 h storm if the contour strip area was approximately 2% of the runoff collection area. Using DEM–derived contour lines, precisely tracked by farm equipment and applied to areas above steep slopes, contour planting of small, select areas of a field will improve soil and water conservation in tillage systems. The method can be implemented using commercially available mapping software and autosteering equipment designed for tractors and drills.

Key words: conservation tillage—contour farming—digital terrain model—runoff—soil erosion

Contour farming uses ridges and furrows formed by tillage, planting, and other field operations to change the direction of runoff from directly downslope to around-the-hill slope (USDA 2007). As prescribed by the USDA Natural Resources Conservation Service (USDA NRCS), contour furrows have sufficient grade to ensure that runoff water does not pond and cause unacceptable crop damage. In the inland Pacific Northwest (PNW), where water is the primary limitation to crop production, crop damage is not a concern, and evenly distributed detention of all precipitation is desired. Thus, furrows without an outlet placed on level contours would essentially provide detention storage while infiltration occurs—thus preventing overland flow, controlling erosion, and reducing stream sedimentation.

Contour furrowing applied in conventional tillage has been estimated to decrease soil erosion two to three fold. Shipitalo and Edwards (1998) reported a decrease from 15.7 Mg ha^{-1} y^{-1} (7.0 tn ac^{-1} yr^{-1}) to 4.7 Mg ha^{-1} y^{-1} (2.1 tn ac^{-1} yr^{-1}) in soil erosion from otherwise conventionally farmed corn in Ohio. Based on the Universal Soil Loss Equation and the Agricultural Non-Point Source Pollution Model evaluations, estimates of contour furrowing effectiveness in Nebraska indicated a halving of erosion from 42 Mg ha^{-1} y^{-1} (18.7 tn ac^{-1} yr^{-1}) to 21 Mg ha^{-1} y^{-1} (9.4 tn ac^{-1} yr $^{-1}$) (Jones et al. 1990). Similar results were obtained from small grain rotations in central western Idaho by Prato and Wu (1991).

Adoption of contour furrowing, however, has been associated with increased costs resulting from reduced efficiency of field operations (Jones et al. 1990) and on complex slopes efforts to maintain contour results in point rows and gaps, truncated furrows, and more time spent in the field. Truncated furrows, where placed on the USDA NRCS recommended row grade of less than 0.2%, result in accumulation sites for runoff and rill formation. Equipment operator efforts to maintain level furrows are hampered by how well drills track behind power equipment and the operator's skills at perceiving and maintaining a level contour path. In tilled soil, drills slide downslope, destroying furrows and burying seed. Runoff, rill development, and ultimately, gully formation might actually increase if furrows concentrate flow on concave slopes (Frazier et al. 1983; Quinton and Catt 2004; Deasy et al. 2010). In fact, the USDA NRCS (2007) conservation practice standard states that contour farming is most effective on slopes between 2% and 10%. In addition, it is not well suited to rolling topography having a high degree of slope irregularity. This limitation is especially troublesome in the Pacific Northwest, where slopes over 30% are routinely farmed.

Winter wheat (*Triticum aestivum* L.)–summer fallow is the dominant cereal production system on 1.56 million ha (3.86 million ac) on the Columbia Plateau of the inland PNW receiving <300 mm y^{-1} (<11.8 in

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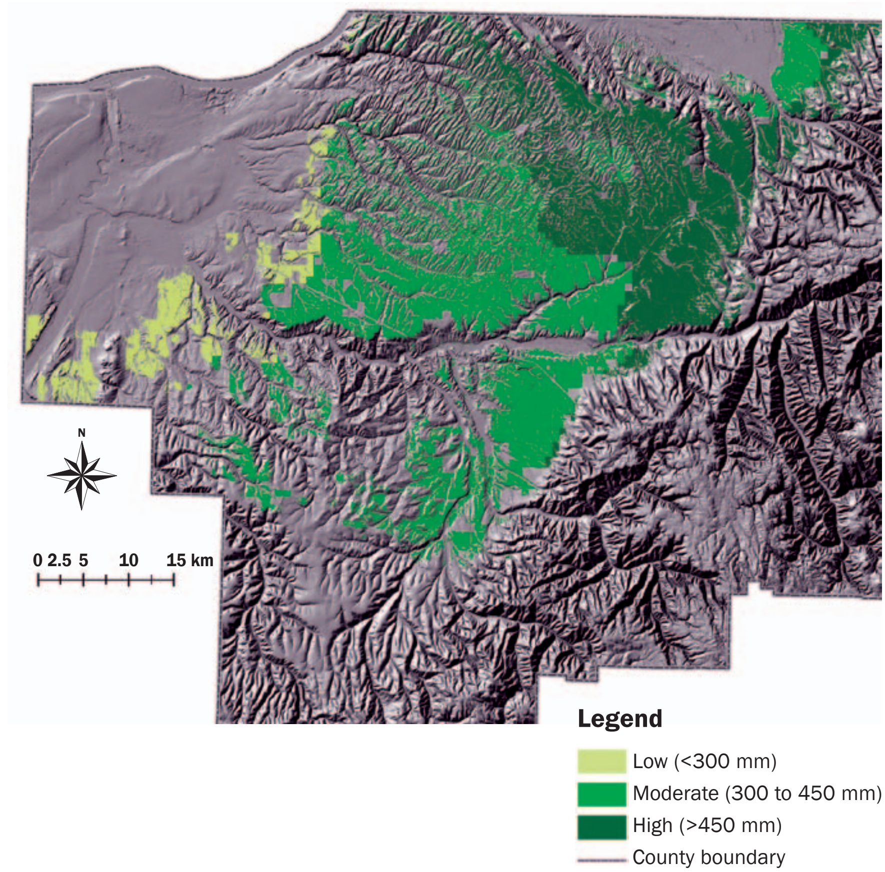
yr^{-1}) (Schillinger and Papendick 2008). It is also widely used in the southeastern area of the region, where precipitation is 300 to 450 mm y^{-1} (11.8 to 17.7 in yr^{-1}), and evaporative demand during the growing season exceeds available water from precipitation (Schillinger and Papendick 2008). Within Umatilla County, Oregon, dryland wheat is produced on approximately 116,300 ha (287,382 ac); approximately 65% of the area (76,300 ha [188,541 ac]) receives less than 450 mm (17.8 in) of precipitation (figure 1). With rare exceptions, this system depends on fallow through multiple tillage operations to control weeds and store soil water during fallow. These operations create a dust-mulch low in soil organic matter and bereft of plant residue.

By definition, conservation tillage results in 30% or more surface residue after seeding. Where precipitation exceeds 450 mm y^{-1} (17.7 in yr^{-1}) in the eastern part of the region, residue cover in excess of 60% at seeding is possible following both conservation tillage and no-tillage management (Williams and Wuest 2011). However, efforts to leave effective levels of crop residue on the soil surface in areas of lower precipitation are hampered by low productivity. Chemical fallow and no-till are not widely adopted in areas where precipitation and seed zone moisture are often inadequate for early planting of winter wheat, which if feasible, would provide soil cover during fall and winter (Schillinger and Young 2004). Delaying planting until late fall rains replenish seed zone soil water reduces wheat yields by up to 25% (Donaldson et al. 2001). A lack of residue cover combined with severe weather events results in extreme water erosion during winter and spring and wind erosion through late fall (Sharratt and Feng 2009). Water erosion occurs primarily through rill erosion occurring from December through March (Zuzel et al. 1982) as water concentrates on plateau summits and flows over shoulders and backslopes.

A possible solution to these problems lies in combining old technology (i.e., deep furrow drills) with new technology (i.e., global positioning system [GPS] guidance systems for tractors and drills and digital elevation models [DEMs]). Deep furrow drills have been used in the Pacific Northwest since 1966 to provide producers the ability to seed into soil moisture beginning in early September and have the wheat germinated and growing before the arrival of winter. Furrow depths are typically 20 cm (7.9 in) deep and would appear to provide substantial detention storage for excess rainfall. A single pass of such a drill, properly positioned along the contour of the shoulder slope immediately below a plateau summit, might be enough to protect the whole slope from runoff from the summit. Guidance or autosteer systems for agricultural equipment could be programmed to follow a preprogrammed path that coincides with a level contour identified using a DEM. Installing these systems on both power equipment and drills provides us with the opportunity to precisely create level furrows. Time and resources can be saved by strategically creating level furrows only where they are needed over an adequate area to capture runoff from plateau summits and shoulders.

Figure 1

Plateau and ridge slope areas that might benefit from contour planting at the top of the shoulder slope in dryland wheat producing areas of Umatilla County, Oregon.



Our working hypothesis was that we could strategically establish a limited number of deep furrow drill passes on precise contours using GPS technology to capture excess runoff from upland plateaus and prevent it from flowing in concentrated rills down the surrounding steep slopes. The objectives of this study were to (1) assess the potential for contour planting for capturing water that collects on plateaus and would otherwise run off and form severe rills and (2) determine the resolution and accuracy of terrain representation by DEMs for deriving routing information for planting on elevation contours. Contours developed from three grid-cell-size DEMs were evaluated at 3, 6, and 9 m (9.8, 20, and 29.5 ft) in accordance with standard implement widths that might be used for normal field operations, while simultaneously collecting elevation data.

Materials and Methods

Site Description. Research was conducted within an 11 ha (27 ac) farm field near Echo, Oregon (45°43'20"N, 119°03'01"W). The climate is semiarid continental with 70% of mean annual precipitation (280 mm [11.02 in]) falling between November and April. Soils are derived from loess parent material and are classified as Ritzville silt loam (Coarse-silty, mixed, superactive,

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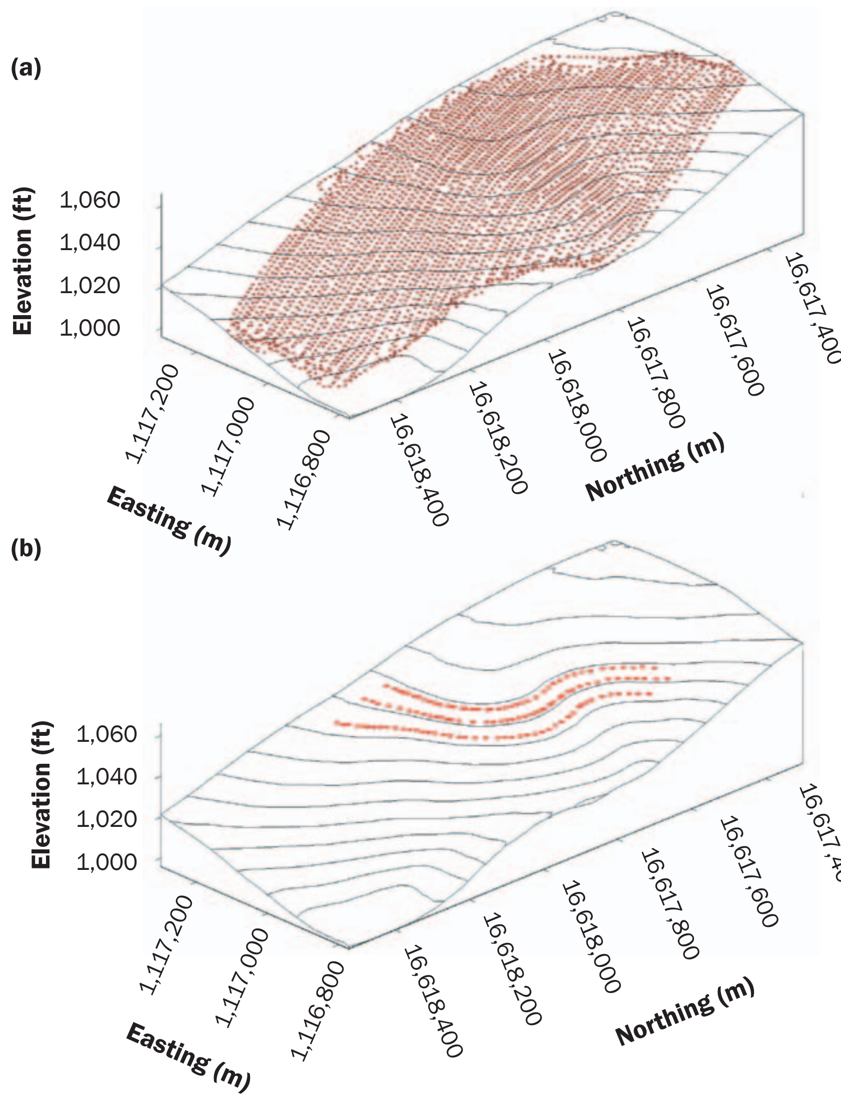
mesic Calcidic Haploxerolls) with 8% to 12% slopes. Topography is a dissected plateau with 33 m (100 ft) of vertical relief. At the time of this research, the field was in the fallow phase of a winter wheat–fallow rotation and had been chisel plowed, cultivated, and rod-weeded in the fall of the previous year following harvest.

Contour Capture Potential. We used a tripod-mounted self-leveling laser to pan across the hillside and place small flags to identify elevation contours on a 5% to 8% slope above a 30% shoulder slope. A human operator then guided a tractor with a deep furrow drill (10 openers spaced 35.6 cm [14 in] apart, 3.7 m [140.2 in] [total width]) along the flagged, predetermined contour. Our intent was to maximize furrow capacity with sufficient vertical control to prevent low spots where runoff could concentrate and overflow the furrow. Furrow capacity is the detention storage volume after weathering from December through March, when erosion is most likely to occur (Zuzel et al. 1982). Furrows were 20 cm (8 in) deep, 35.6 cm (14 in) apart, and 200 m long (figure 2).

Previous work conducted nearby on the upland plateau (<5% slope) has shown that under the poorest of soil conditions (inversion tillage, unfertilized, crop residue burned), the ratio of runoff to storm precipitation (Q/P) equals 0.16 (Williams 2004). Analysis of 856 storms recorded from 2001 through 2009 shows 99.5% with rainfall rates less than 1 mm h^{-1} (0.04 in hr^{-1}), mean intensity of 1 mm h^{-1} (0.04 in hr^{-1}), and mean depth and duration of 4 mm (0.14 in) and 6.6 h. The first and second maximum intensity storms were 38 mm h^{-1} (1.59 in hr^{-1}) and 7 mm h^{-1} (1.59 in hr^{-1}), accounting for <0.2% of the storms. Under these conditions, storm duration is more important for the development of runoff and soil erosion events that develop with the slow accumulation of excess water that concentrates on plateau summits and then cascades over shoulder slopes and down and across back and toe slopes. At these low rainfall rates, rainfall contribution to the contour furrow area is minimal compared to the flow coming into the area from the plateau summit. Infiltration rates increase with pressure head (depth) (Green et al. 1986)—thus as the furrow fills, the infiltration rate increases to constant intrinsic percolation rate determined by soil saturation. Because the soils in this region are well-drained silt loams and are generally deep enough to accommodate total

Figure 2

Three-dimensional topographic representation of the field with points where the global positioning system, survey-grade receiver was used to obtain elevation readings along (a) a series of parallel transects and (b) three reference contours and to check contour elevations from the digital elevation model.



inflow of rainfall and snowmelt, we assumed that saturation is not attained and is not a limiting factor. The goal is to provide an infiltration gallery sufficient to deal with the inflow, which requires balancing inflow from 24 h storms (USDC NOAA 1973) from contributing areas that will vary depending on field of application. Thus, to estimate the potential capacity of contour furrows to capture and infiltrate overland flow, we poured water into two summit furrows that connected with the contour furrows. The water source was a portable water tank (7.24 m^3 [1,911 gall]) by hose (figure 3). Measurements included flow rate, time to drain the tank, and area of standing water in furrows. We applied a depth equivalent of 57 mm (2.2 in) into an area of 128 m^2 (0.03 ac) in 1.6 h (35 mm h^{-1} [1.39 in hr^{-1}]), well in excess of expected rainfall rates. As a test of concept, we assumed this is the maximum field infiltrability we could use in calculating the area needed to capture and infiltrate runoff. Potential runoff was estimated as Q/P = 0.16 for 6 and 24 h storms of various return periods from contributing areas defined by (1) property boundaries and farming practices and (2) by geographic information system–interpretation of DEM data. This water detention area estimate is conservative (or larger than what

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Figure 3

One pass with a deep-furrow drill precisely contoured on the shoulder can capture the runoff from a 100 y, 24 h storm if it is 2% of the runoff collection area. The furrows have overwintered through multiple freeze-thaw and rainfall events.

Table 1

Rainfall by return period for 24 h and 6 h storms for foothills of Blue Mountains near Echo, Oregon, and the area and number of passes of a 3.7 m wide, deep-furrow drill required for 6.57 ha contributing area.

Return period (y)	Rainfall (mm)	Area (ha)	Number of passes
24 h storms			
100	64	0.13	1
50	56	0.11	1
25	53	0.11	1
10	43	0.09	1
5	38	0.08	1
2	30	0.08	1
6 h storms			
100	38	0.08	1
50	36	0.07	1
25	30	0.06	1
10	28	0.05	1
5	24	0.05	1
2	19	0.04	1

is likely to be needed) because it is based on a Q/P ratio derived from cropping practices that were an extreme example of poor management (Williams 2004). From these calculations, we prescribe the number of precisely contoured passes required with a 3.7 m (12 ft) wide deep furrow drill to intercept runoff at the shoulder slope.

Terrain Modeling Procedures. A professional surveying firm was hired to collect elevation data that could be used to produce a DEM of the field. Position data in Universal Transverse Mercator coordinates (WGS84 datum) were collected using a survey-grade GPS system. Readings were taken every 2 s from an all-terrain vehicle traveling at a speed of 2 m s^{-1} (4 mi hr^{-1}) along evenly spaced 3 m (10 ft) transects (figure 2). The GPS system was a 24 channel, dual-frequency receiver with real-time kinematic technology, providing an accuracy of ±10 mm (±0.8 in) in the horizontal plane and ±20 mm (±1.6 in) in the vertical plane.

Mean distance between points was 2.67 ± 0.59 m (8.75 ± 1.92 ft). The Spatial Analyst extension of the geographic information system software ArcGIS v. 9.3 (ESRI, Redlands, California) using default settings was used to generate three DEMs corresponding to spatial resolutions of 3, 6, and 9 m (9.8, 20, and 29.5 ft). To simulate data collected by farm equipment with corresponding widths, the 3 m DEM was created using the elevation data from all transects, the 6 m DEM was created using data from every second transect, and the 9 m DEM was created using data from every third transect. Four surface models were created for each DEM using the following interpolation methods: natural neighbor, inverse distance–weighted, kriging, and regularized spline. Mathematical theory behind these interpolation methods is beyond the scope of this paper. Interested readers may wish to consult Childs (2004) for further details.

Statistical Analysis of Reference Contour Positions. Three reference elevation contours were also established in the field 10 m (33 ft) apart on a common slope (figure 2). Each contour was delineated by flags placed approximately 5 m (16 ft) apart using the previously described procedure involving the self-leveling laser. The survey-grade GPS receiver was again used to register the horizontal and vertical locations of the flags that delineated each of the contours.

The mean elevation of the flagged points was computed for each reference contour line. Contour lines at the same mean elevations were generated using Spatial Analyst of ArcGIS and values for each of the three DEMs. Accuracy of the DEM–based contours was determined by measuring the horizontal (planar) and vertical distance between the nearest point on the reference contour to the DEM–based contour. The error in elevation was determined by comparing the reference value with the predicted value that was derived from a DEM.

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Figure 4

Schematic of contour furrow application to a winter wheat field. The field is bounded on the south and west by a perennial grass draw and on the east by a neighboring field, both of which are hydrologic boundaries resulting from tillage erosion. Light gray elevation contours (2 m) were developed from a 10 m digital elevation model. Precision contours shown in dark black were generated using a laser level. Arrows indicate direction of plateau seeding, which controls flow in the contributing area above the shoulder slope. Only one of the three precision contour locations shown here would be chosen for creating on-contour furrows to capture runoff from the plateau.

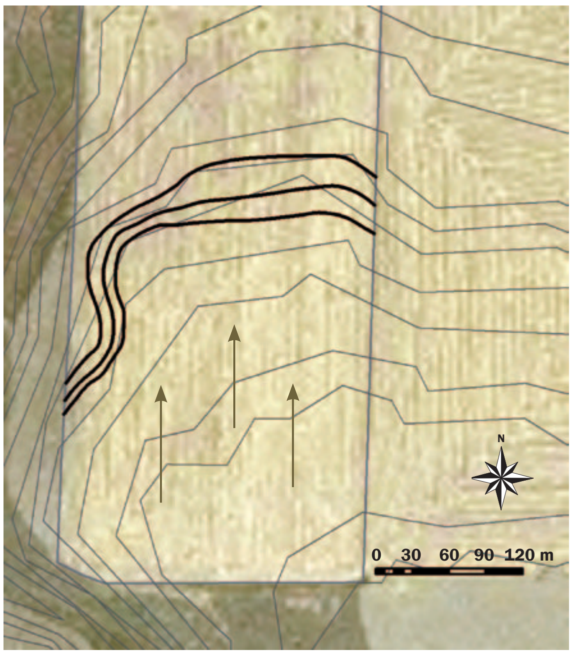

Table 2

Maximum differences and root mean square errors found between reference points and nearest point on contour polyline in the horizontal and vertical axes.

DEM (m)	Max_p (cm)	$RSME_p$ (cm)	Max_z (cm)	$RSME_z$ (cm)
3 m				
NN	72	10	7	1
IDW	89	14	13	1
Krig	77	10	7	1
RSI	87	10	8	1
6 m				
NN	189	17	10	2
IDW	139	22	16	2
Krig	106	15	10	2
RSI	103	15	10	2
9 m				
NN	102	18	11	2
IDW	141	28	19	3
Krig	96	17	10	2
RSI	85	12	7	1

Notes: Max_p = maximum distance in the planar axes. $RSME_p$ = maximum root square mean error on the planar axes. Max_z = maximum distance in the vertical axis. $RSME_z$ = maximum root square mean error on the vertical axis. NN = natural neighbor interpolation. IDW = inverse distance weighted interpolation. Krig = kriging interpolation. RSI = regularized spline interpolation.

Maximum differences in horizontal and vertical values and root mean square error (RMSE) were calculated. The RMSE is a measure of how well modeled values match observed values, with low values indicative of good modeling accuracy. The RMSE is given by

$$\mathrm{RMSE} = \sqrt{\frac{\Sigma_{i=1}^{n} (O_i - P_i)^2}{n}},$$

where O_i is the value of the ith observation, P_i is the value of the corresponding ith prediction, and n is the number of observations.

Results and Discussion

Contributing areas will vary from field to field, and corresponding treatment area will need to be recalculated—a task that is easily accomplished using a computerized spread sheet. Demonstrating this concept (figure 4), contour furrows were placed where the slope steepens on the western edge of the field and then were extended to the opposite (eastern) field boundary. The entire field south of the highest contour furrow is potential contributing area because overland flow is directed cross-contour by seed furrows or property boundaries. Field edges typically are barriers to inter-field flow because of tillage erosion that essentially leaves a dam or levee separating the fields. In this example, the contributing area is 6.57 ha (16.23 ac), and the area of contour furrows needed for a 100 y, 24 h, 64 mm (2.50 in) storm is 0.13 ha (0.32 ac) of contour furrow or 1% of the contributing area. This could be obtained by one pass with a 3.7 m (12 ft) wide deep-furrow drill (table 1). Similarly, to protect against a 100 y, 6 h storm of 38 mm (1.50 in) of rainfall, 0.08 ha (0.19 ac) would be needed. Again, one pass with the same drill would be sufficient.

The maximum difference in horizontal and vertical distances between the reference and modeled contour lines increased with decreasing DEM resolution from 3 to 6 to 9 m (9.8 to 20 to 29.5 ft) (table 2). However, the RMSE was ≤3 cm (≤1.2 in). The maximum vertical error (19 cm [7.5 in]) is less than the furrow depth (20 cm [7.9 in]). These results suggest that acquiring elevation measurements on a transect spacing of 9 m (29.5 ft) might be suitable for producing a DEM having sufficient resolution for precision contouring. This transect spacing corresponds to the width of many drills and other farm implements, which means the maps could be made during normal field operations. The best

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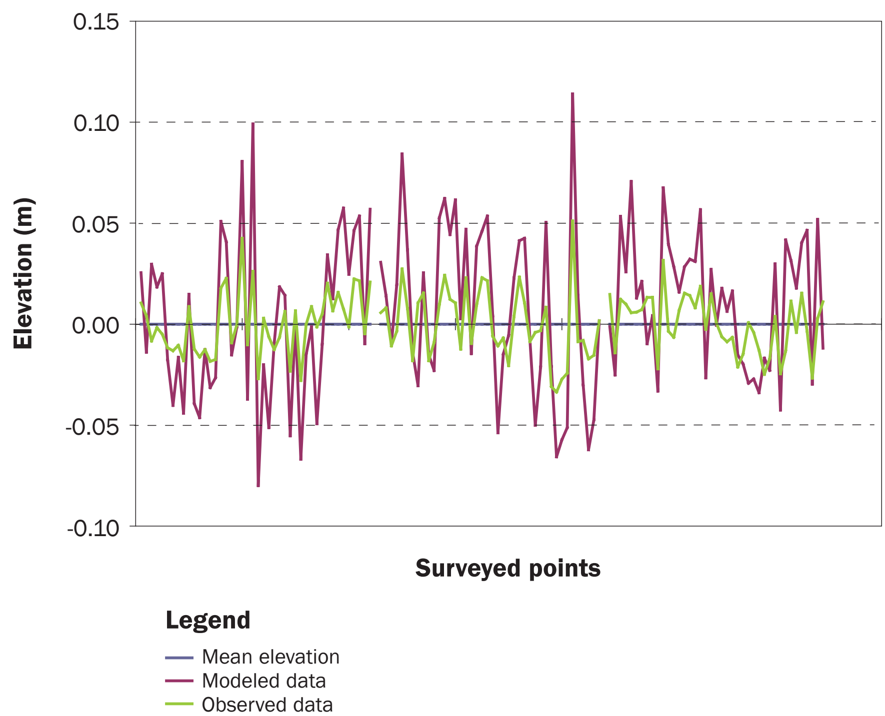
interpolation methods for generating DEMs and contour lines were the regularized spline and kriging methods, which yielded the least RMSE for a given DEM resolution. In comparison, the results for the nearest neighbor and inverse distance weighted methods indicated poorer performance.

Surveyed values for the contoured furrows show a maximum vertical difference of 8 cm (3.2 in) between low and high points within the furrow, with the modeled data closely representing the observed data variability around the mean elevation of the furrows (figure 5). The maximum difference between the highest points and the lowest points in the modeled data (regularized spline, 9 m [29.5 ft] DEM) was 18 cm (7.9 in). This value is well within the ±15 cm (±5.91 in) vertical accuracy needed for soil erosion modeling (Grenzdörffer and Donath 2008). As demonstrated by the low maximum $RSME_z$ on the vertical axis values, the modeled data closely tracked the deviation from the mean in the observed data, with a nearly regular pattern of values above the mean, followed by values below the mean. This pattern could distribute flow from the contributing area sufficiently to prevent concentration and cascading failure downslope. Furthermore, over winter furrow integrity and contour accuracy requirements can be reduced by moving upslope to a less steep shoulder position, which would also have the effect of reducing the size of the contributing area.

Figure 5
Variability around mean furrow elevations as surveyed using real-time kinematic global positioning system and modeled using regularized spline interpolation on a 9 m raster grid.



Implementation of Contour Planting. Today's farm equipment guidance systems steer tractors along straight and curved paths established relative to a visible reference, such as a field boundary. The operator begins by inputting a starting point, driving along the boundary, and inputting the end point of the base line. These systems use a steering actuator for guiding wheels in response to a steering controller. The controller receives input from a steering angle sensor measuring the angular position of the steerable wheels and a tractor position unit (GPS receiver) generating actual position data. The controller compares the actual position with the desired position and instructs the steering actuator to steer the wheels in the correct direction.

Because elevation contours are invisible, they must be delineated manually and driven upon (as described above) for their recording into the memory of an automatic guidance system. New automatic steering technologies, however, are beginning to emerge that are capable of autonomously guiding tractors along elevation contours. For example, Trimble Navigation Limited (Sunnyvale, California, USA) recently developed the AgGPS Field Level II system that acquires elevation data and applies this information into control of machinery for land-leveling operations. Procedures for adapting this system for contour planting are briefly described in the following paragraphs.

Elevation data for a DEM can be collected using the Trimble AgGPS 442 or AgGPS 432 receivers and logged into memory on the AgGPS FmX integrated display. These receivers provide centimeter-level accuracy while connected to an real-time kinematic base station. Survey with a GPS receiver involves collecting elevation measurements along a series of parallel transects. Performed as an independent operation, the collection of GPS data requires a large amount of time to cover fields on multiple transects while obtaining elevation measurements. However, this problem is solved by collecting these data during regular farming operations, such as tilling, spraying, or harvesting.

The resulting elevation data can be exported from the FmX integrated display to the new Surface module of the Farm Works (Hamilton, Indiana, USA) office software suite. Interpolation of elevation data can be performed in Surface to create a DEM of the required resolution. The DEM can be displayed on the screen of a personal computer from any angle with elevation contours from any angle. Drawing tools are available for delineating the contour line representing the desired route of the tractor on the slope. These line features are then exported back into the memory of the FmX integrated display. Together with the FmX display and real-time kinematic positioning accuracy, this information can be then used to accurately guide a tractor equipped with Trimble implement steering technology on the desired elevation contour. The same route could be used again in each following year. Furthermore, the Trimble technology is capable of controlling tractors and towed tillage implements against downward slippage on sloping land.

Summary and Conclusions

A system of GPS–based guidance for planting on the contour was proposed as a strategy to increase water infiltration and reduce runoff and soil erosion in the inland PNW.

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Field experiments were performed to evaluate its potential for capturing water above steep slopes and determine the resolution and accuracy of a DEM for deriving routing information for contour planting. We demonstrated that a strip of deep-furrow seeding precisely contoured on the upper shoulder slope provides sufficient detention storage to capture and hold runoff from a 100 y, 24 hr storm, if the contour strip area is approximately 2% of the runoff collection area. In practice, the area would likely comprise two or more passes of a 9 to 18 m (30 to 60 ft) wide drill, which increases the robustness of the contour water collection area. The results indicated that a DEM having a resolution of 9 m, corresponding to the width of many farm implements, was sufficiently accurate for predetermining the path for autonomous travel along an elevation contour. Contour planting can be implemented using newly available steering systems that allow for autonomous navigation of tractors along curved paths based on contour lines that have been delineated using appropriate mapping software and a DEM. The elevation data for this purpose can be easily acquired using a GPS survey-grade receiver in association with normal tillage operations when a tractor is travelling over a field. Precision contouring with a deep furrow drill may be an effective conservation practice with only small changes in the farmer's current practice.

This concept has the greatest potential in the intermediate and low precipitation zones of the inland PNW small grain growing region. Because this management tool is conceptual and based on limited field data, it would benefit from field trials at multiple locations. Due to the sporadic nature of runoff events, it will likely require observation of many fields over many years before convincing evidence of the practice's effectiveness is accumulated.

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References

Childs, C. 2004. Interpolating surfaces in ArcGIS spatial analyst. ArcUser July-Sep:32-35.

Deasy, C., J.N. Quinton, M. Silgram, A.P. Bailey, B. Jackson, and C.J. Stevens. 2010. Contributing understanding mitigation options for phosphorus and sediment to a reveiw of the efficacy of contemporary agricultural stewardship measures. Agricultural Systems 103:105-109.

Donaldson, E., W.F. Schillinger, and S.M. Dofing. 2001. Straw production and grain yield relationships in winter wheat. Crop Science 41:100-106.

Frazier, B.E., D.K. McCool, and C.F. Engle. 1983. Soil erosion in the Palouse: An aerial perspective. Journal of Soil and Water Conservation 38(2):70-74.

Green, R.E., L.R. Ahuja, and S.K. Chong. 1986. Hydraulic conductivity, diffusivity, and sorptivity of unsaturated soils: Field methods. *In* Methods of Soil Analysis, ed. A. Klute, 771-798. Madison, WI: Soil Science Society of America.

Grenzdörffer, G., and C. Donath. 2008. Generation and analysis of digital terrain models with parallel guidance systems for precision agriculture. *In* Proceedings of the 1st International Conference on Machine Control & Guidance, 333. ETH Zurich.

Jones, A.J., R.A. Selley, and L.N. Mielke. 1990. Cropping and tillage options to achieve erosion control goals and maximum profit on irregular slopes. Journal of Soil and Water Conservation 45(6):648-653.

Prato, T., and S. Wu. 1991. Erosion, sediment, and economic effects of conservation compliance in an agricultural watershed. Journal of Soil and Water Conservation 46(3):211-214.

Quinton, J., and J. Catt. 2004. The effects of minimal tillage and contour cultivation on surface runoff, soil loss and crop yield in the long-term Woburn Erosion Reference Experiment on sandy soil at Woburn, England. Soil Use and Management 20:343-349.

Schillinger, W.F., and R.I. Papendick. 2008. Then and Now: 125 Years of Dryland Wheat Farming in the Inland Pacific Northwest. Agronomy Journal 100:S-166-S-182.

Schillinger, W.F., and D.L. Young. 2004. Cropping Systems Research in the World's Driest Rainfed Wheat Region. Agronomy Journal 96:1182-1187.

Sharratt, B.S., and G. Feng. 2009. Windblown dust influenced by conventional and undercutter tillage within the Columbia Plateau, USA. Earth Surface Processes and Landforms 34:1323-1332.

Shipitalo, M.J., and W.M. Edwards. 1998. Runoff and erosion control with conservation tillage and reduced-input practices on cropped watersheds. Soil & Tillage Research 46:1-12.

USDA NRCS. 2007. Contour farming. Natural Resources Conservation Service - Conservation Practice Standard. Code 300.

USDC NOAA. 1973. Atlas 2, Vol. 10. Precipitation frequency atlas of the western U.S., Oregon. Government Printing Office. Washington, DC.

Williams, J.D. 2004. Effects of long-term winter wheat, summer fallow residue and nutrient management on field hydrology for a silt loam in north-central Oregon. Soil & Tillage Research 75:109-119.

Williams, J.D., and S.B. Wuest. 2011. Tillage and no-tillage conservation effectiveness in the intermediate precipitation zone of the inland Pacific Northwest, United States. Journal of Soil and Water Conservation 66(4):242-249.

Zuzel, J.F., R.R. Allmaras, and R.N. Greenwalt. 1982. Runoff and soil erosion on frozen soils in northeastern Oregon. Journal of Soil and Water Conservation 37(6):351-354.

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